JACOBS PUBLISHERS

OPEN ACCESS

# Jacobs Journal of Sports Medicine

Review Article

# On The Measurement of Running Style 1: Risks and Benefits in Transitioning To Barefoot/Minimal Footwear Running

M. Daumer[1*] PhD, C. Kleinmond[2] PhD, C. Stolle[1] MSC, C. Lederer[1] PhD, M. Hilgers[3] MD, M. Walther[4] MD

[1]*SLCMSR e.V./The Human Motion Institute, Munich, Germany*

[2]*ClinProject Eurasburg, Germany*

[3]*Sports Medicine, Level One Orthopedics, Orlando, FL, USA*

[4]*Department of Foot and Ankle Surgery, Schoen Klinik Munich, Germany*

**Corresponding author: Dr. Martin Daumer, SLCMSR e.V. The Human Motion Institute, Munich, Germany, Email: daumer@slcmsr.org*

*Received:* 06-09-2015

*Accepted:* 07-15-2015

*Published:* 07-28-2015



## Abstract

**Background:** The individual running style has an impact both on running performance and on running injury risk. The runner aiming to improve his running style finds himself confronted with contradicting recommendations from the literature [1-8] and there exist even smartphone apps, social platforms, video tools etc. claiming to coach the runner towards a healthier running style. The goal of this paper is to present quantitative estimates for the risks and benefits in transitioning to barefoot/minimal footwear running from our recent cross-sectional on-line study.

**Methods:** We designed and performed an on-line survey using in a community of minimal footwear/barefoot (mf/b) runners. The sample consisted of runners who successfully switched to mf/b running, without a formal distinction between professionals and amateurs.

The on-line survey was performed using Google forms; the raw data are publicly available under https://docs.google.com/spreadsheets/d/19urx4eM-t9CgJEXQUOtHbax_fngP_5DBz5EZHzFSNAk/edit?pli=1#gid=0. All statistical analyses were performed in R 3.1.2. [9]

**Results:** In total 226 runners filled out the questionnaire, 15 subjects were excluded from the analysis due to invalid data. From this data set, only those subjects were included in the analysis who reported at least 50 km in each running phase (shod, transition, mf/b) (173 (82%) subjects, 137 male, 15-71 years of age [mean=40, sd = 9.8]). The mean numbers of injuries per 10.000 km in three phases where 8.0 [sd=16.2], 23.4 [sd = 48.8], and 3.5 [sd=15.7] respectively.

The variance of running related injuries was significantly increased during the transition period from shod running to mf/b and the detailed analysis (different trends for mean and median) suggests that there is a subgroup of runners with highly increased risk of injury during this phase.

The injury rate per km was markedly lower – about 50% - in mf/b than in shod running; this reduction of injuries however should be considered with care due to possible selection bias.

**Discussion/Conclusion**: Of course, there is considerable risk for bias in this study. Nevertheless, we could confirm the folklore of the increased injury risk during the transition phase and give a lower limit (at least threefold increase of the injury risk). Future research about the individualized management of the transition phase (intensity, recovery etc.) is warranted.

## Introduction

There is an ongoing debate about the risks and benefits of running in different footwear (cushioned sport shoes, minimal, barefoot) in natural environment.

E.g. Ryan et al. [8] conclude that "Running in minimalist footwear appears to increase the likelihood of experiencing an injury". Hryvniak et al. [7] state that "the survey results indicated that majority of barefoot runners had previous running injuries that resolved after starting barefoot running programs" whereas "The results suggest that a large percentage of this sample of runners experienced benefits or no serious harm from transitioning to barefoot or minimal shoe running."

These apparently contradictory results are probably due to the fact that these studies refer to different time scales and do not respect the transition phase as the possibly most critical risk factor. The increased risk during the transition phase is folklore amongst runners (see also [6]), but has not yet been quantified to our knowledge.

Daoud et al. [4] give quantitative estimates of the benefits of forefoot striking vs. rear foot striking and argue that habitually shod runners exhibit forefoot striking when asked to run barefoot. The ecological validity of the foot strike patterns observed in the laboratory however has not been proven.

Here we focus on methods and results of an online survey in a community of minimal footwear/barefoot (mf/b) runners. The aim of the survey was to investigate the viability of the method and to record first insights on running behavior, distance performance and injuries.

## Methods - A survey with the social network of the "barefoot runners society"

An online questionnaire was set up using Google forms (fig. 1, see Pages 6&7) and advertised by the "barefoot runners society" website (http://thebarefootrunners.org/threads/update -newstudy-being-conducted-running-injuries-in-shod-vs-minimal-footwear-barefoot-runners.12871/ twice (see fig. 2) with an automatic post on Facebook and Twitter and by the online-newsletter and Facebook of the "freeheel runningpad" ( https://www.facebook.com/RunningPad).

Runners were eligible to fill out the questionnaire, if they used to run with regular running shoes, but, after a certain transition phase, have been running mostly either in minimal footwear or barefoot.

The subjects were asked about their sex, age and running habits. This included running related injuries (e.g. Plantar Fasciitis, Achilles Tendinitis, IT Band Syndrome, Runner's Knee, and Shin Splints), the weekly distance and duration of months or years for each period of shod running, transition phase and mf/b running. Furthermore the subjects were asked for their personal opinion on benefits and risks of mf/b running and their reason why they changed their running style.

Unlike in clinical trials or epidemiological studies, we have neither obtained a signed written informed consent nor a formal external ethics approval. The participants have just read the explanation "We will not collect any personal information about you. Results of the survey and comments will be published. By submitting the questionnaire you thereby agree with these terms and conditions", and have then decided to fill in the questionnaire) nor any information about demographics (apart from sex and age) and no trusted third party data (such as a hospital/physician with a link list that links patient ID with the actual name/address etc.) that would allow to identify an individual.

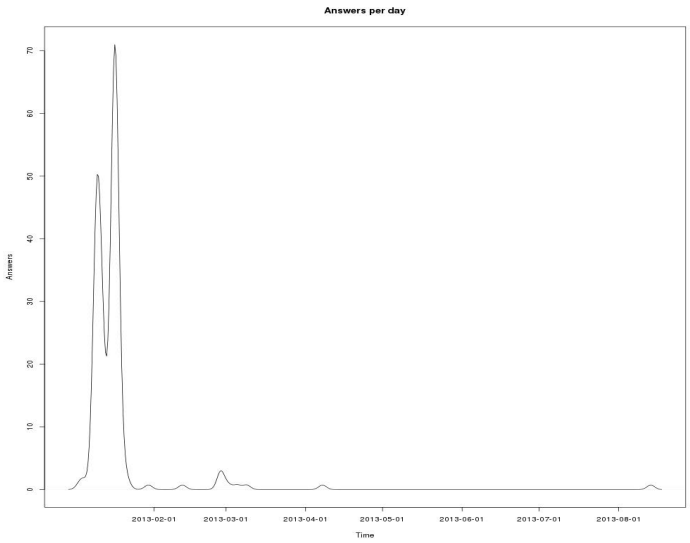


**Figure 2.** Number of questionnaires filled out per day. The second peak corresponds to a second announcement of the questionnaire.

## Results

In total 226 runners answered the questionnaire, data from 15 subjects could not be included in the analysis due to invalid

data. From this data set, only those subjects who reported at least 50 km in each running phase (173 (82%) subjects 137 male, ages 1571 years [mean=40]) were used for analysis.

**Table 1.** Distance per week (km) as well as duration (years) for each period in total dataset (male/ female).

| Number | 173 (137 male, 35 female, 1 not defined) | | | |
|---|---|---|---|---|
| | Distance per week (km) | | Duration (years) | |
| | Mean (male/female) | SD (male/female) | Mean (male/female) | SD (male/female) |
| Shod | 29.2 (31.0/22.4) | 23.1 (24.7/14.0) | 10.9 (11.5/9.1) | 10.5 (10.9/8.6) |
| Transition phase | 21.4 (22.3/17.5) | 18.0 (19.0/13.3) | 0.54 (0.57/0.42) | 0.41 (0.43/0.31) |
| mf/b | 37.1 (38.9/29.7) | 26.0 (27.5/17.9) | 2.8 (3.0/2.2) | 2.9 (3.2/1.2) |

mf/b: minimal footwear/barefoot runners

In order to transform the free text data into a homogeneous, analyzable format, the following rules were applied:

1) Comments like “too many” or “many” were counted as three injuries.

2) Plural forms of explicitly named injuries were counted as two injuries.

3) Mean distance was used if weekly distance entries had the format “from...to”.

The variance of running related injuries was markedly increased ($p < 0.01$, paired Bonett-Seier variance test) during the time period of changing from shod running to mf/b (see figure 3).

The mean injury rate per km was markedly lower ($p < 0.01$) – about one half - in mf/b than in shod running. Although this is formally significant ($p < 0.01$), we believe that this reduction of injuries should be considered with care due to possible selection bias (selection of runners, who “survived” the transition phase).

| Injuries / 10.000 km | Mean | Standard deviation |
|---|---|---|
| Shod | 8.0 | 16.2 |
| Transition phase | 23.4 | 48.8 |
| mf/b | 3.5 | 15.72 |

**Table 2.** Calculated mean of injuries per 10.000 km for shod running, transition phase and minimal footwear/barefoot running (mf/b) and their standard deviations.

Assuming a strong link between mf/b running and forefoot strike running, this reduction is consistent with [Daoud]. However, at least for non-elite runners Hatala et al. [5] argue that there is not such a strong link.

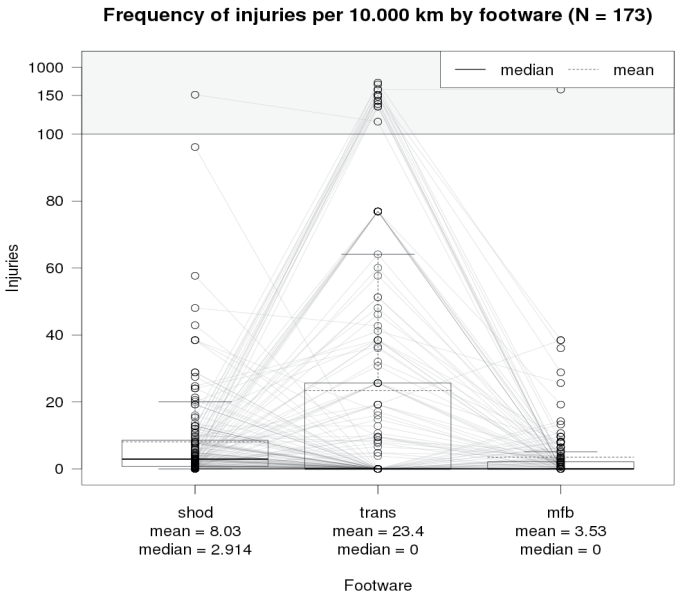


**Figure 3**. Box plots of running injuries in the three phases (Shod, transition and minimal footwear/barefoot (mf/b). Compare to the graphic in [4].

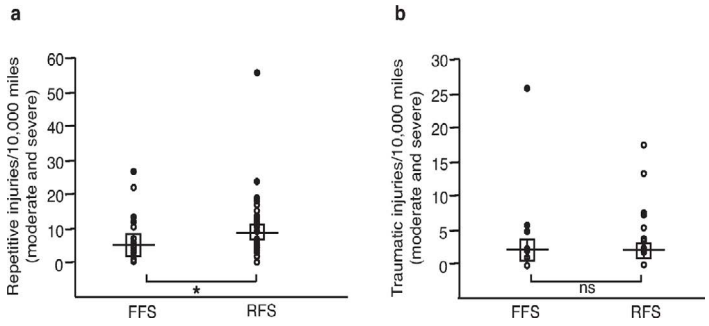


**Figure 4**. Injury rate per 10.000 miles for forefoot (FFS) and rear foot strike (RFS), reprinted from [4] with permission. Boxes indicate mean and SE. (Note that Daoud’s rates are per miles, ours per km. Note also, that Daoud differentiates by running style, not by footwear).

## Discussion

The obvious sources of possible bias are selection bias and underreporting bias.

Concerning selection bias, by design of this study only those runners contributed who “survived” the transition phase. This bias decreases the observed injury rate during the transition phase.

Secondly, a substantial fraction of runners participating in this study changed to mf/b because they experienced injuries in the shod phase. This bias increases the observed injury rate during the shod phase.

Concerning underreporting bias, we argue that injuries from the earlier phases are more likely to be forgotten, i.e. this bias decreases the observed injury rate during the shod phase.

Compared with these sources of bias, we consider other possible biases (e.g. biased perception of injuries from barefoot enthusiasts) as negligible.

These biases cannot be rigorously quantified. However, the style of the free-text answers in the questionnaire suggests that the population underlying this study consists of runners who seem to have a clear memory of their entire running history. Hence, we believe that for the shod phase the selection bias at least compensates the recall bias, i.e. the true injury rate for the shod phase is not higher than the observed rate.

For the findings of this study, this means that

a) the threefold increase of injury rate during the transition phase as compared to the shod phase is a conservative estimate.

b) the twofold decrease during the mf/b phase as compared to the shod phasemight be partially considered as regression to the mean, i.e. the true beneficial effect in typical population of runners is probably smaller than observed in this study.

The increased injury rate during the transition phase seems to be common knowledge (see e.g. [6]) but has never been quantified before to our knowledge. Informal review of the free text filled in the questionnaire (available freely at https://docs.google.com/spreadsheets/d/19urx4eM-t9Cg-JEXQUOtHbax_fngP_5DBz5EZHzFSNAk/edit?pli=1#gid=0) shows that "doing too much too fast" is probably the most important reason.

The observed beneficial effect of mf/b running after mastering the transition phase is compatible with [4]. However, Daout et al. [4] investigated the effect of running style rather than footwear and there is an ongoing discussion about the strength of the link between running style and footwear in various populations [5].

Furthermore, the foot strike patterns from [4] were measured in a laboratory environment, but the ecological validity (running in natural environment) has not been proven.

In our ongoing research on mobile accelerometry, we were able to reproduce foot strike patterns similar to those in [1] in treadmill running using a mobile accelerometer [10]. However, some characteristic elements of these patterns partially disappeared in measurements recorded in a realistic running environment and situation (see fig. 5).

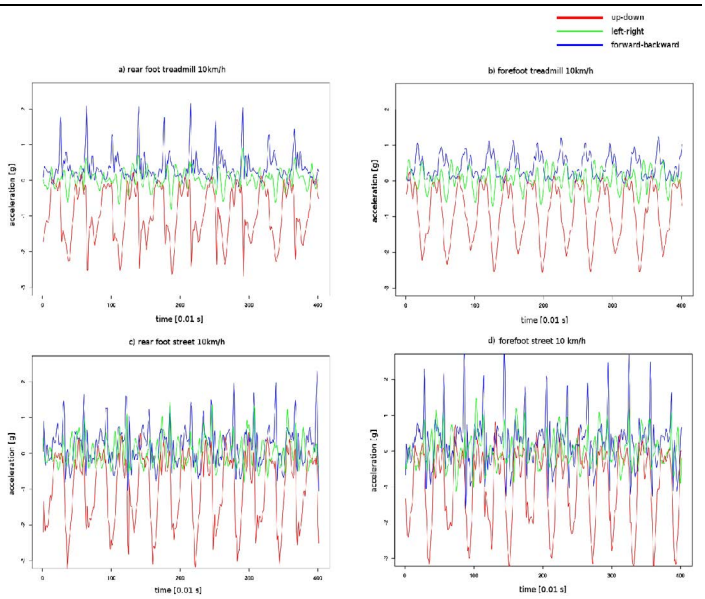


**Figure 5.** Accelerations as measured by a 3D-accelerometer mounted in a belt buckle. On the treadmill (a, b), the patterns in the up-down axis (red) are compatible with the ground reaction forces from [1] and heel strike running is clearly distinguishable from forefoot running. This is no longer the case for outdoor running (c, d).

We consider Lieberman's argument from evolutionary biology [2] concerning the existence of some beneficial effect of barefoot running as plausible. Weak evidence for a beneficial effect is given in [7], which is in our view not sufficient to recommend barefoot running for the general population.

We speculate that special adaptations of the neuromuscular control - which may take years and thousands of kilometers to become effective - play a major role, very similar to the thousands of hours a person needs to play and practice playing the piano before becoming a musician.

The fact is astonishing that the mean injury rate increases by a factor of three during this phase whereas the median rate decreases to zero. Such a behavior could be captured by a zero inflated GLM (suggesting that there are subgroups of runners with highly increased resp. decreased injury risk during this phase). However, the case number and type of variables were not appropriate to perform a sophisticated subgroup analysis.

## Conclusion

"Crowd sourcing" using social networks is an interesting way to generate new evidence in a faster and cheaper way, when compared to standard clinical trials or epidemiological studies; data of sufficient signal to noise ratio can be generated in a very small amount of time.

The risk of injury during the transition phase in the group

of responders ("crowd sourcing") is considerably higher compared to habitually running either shod or mf/b footwear.

Given strong evidence for a considerable risk during the transition phase, the weak evidence of a beneficial effect of barefoot running is in our view not sufficient to justify recommendations for mf/b running for the general population.

In a subsequent publication we will present patterns/parameters extracted from mobile 3D accelerometry measurements which are linked to an individual's running style.

## Acknowledgements

This study was partially supported by the EU (FP7 Easy IMP).

We thank the students of the lecture "clinical applications of computational medicine" at

TUM(http://www.ldv.ei.tum.de/lehre/clinical-applications-of-computational-medicine/) for conducting experiments with mobile accelerometry.

We thank Miriam Porter and the reviewers for valuable criticism and comments.

## References

1. Lieberman D. Foot strike patterns and collision forces in habitually barefoot versus shod runners. Nature. 2009, 463: 531-535.

2. Lieberman D. What we can learn about running from barefoot running: an evolutionary medical perspective. Exerc Sport Sci Rev. 2012, 40(2): 63-72.

3. Bonacci J. Running in a minimalist and lightweight shoe is not the same as running barefoot: a biomechanical study. Br J Sports Med. 2013, 091837.

4. Daoud AI. Foot strike and injury rates in endurance runners: a retrospective study. Med Sci Sports Exerc. 2012, 44(7): 1325-1334.

5. Hatala KG. Variation in Foot Strike Patterns during Running among Habitually Barefoot Populations. PLoS ONE. 8(1): e52548.

6. Goble C, Wegler J, Forest CP. The potential hazards of barefoot running: proceed with caution. JAAPA. 2013, 26(3): 49-53.

7. Hryvniak, David, Jay Dicharry, Robert Wilder. Barefoot running survey: Evidence from the field. Journal of Sport and Health Science. 2014, 2(3): 131-136.

8. Ryan M. Examining injury risk and pain perception in runners using minimalist footwear. Br J Sports Med. 2013, 0: 1–6.

9. R Core Team. R: A Language and Environment for Statistical Computing, Vienna, Austria, 2105.

10. Daumer M. Steps towards a miniaturized, robust and autonomous measurement device for the long-term monitoring of patient activity: ActiBelt. Biomed Tech. 2007, 52: 149–155.